Single Launch Configuration Study Summary

Constellation X

The Constellation X-ray Mission

Con-X Mission Configuration Trade Summary Meeting

October 26, 2005/GSFC

Goddard Space Flight Center

Introduction and Overview

Jean Grady

Con-X Mission Configuration Trade Study
October 26, 2005

Agenda

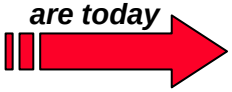
Single Launch Configuration Study Summary	Presenter	Start Time
Intro and Overview: Purpose of Study, Approach, Top Level Performance Requirements, etc.	*Jean – 20 min*	*10:30*
Mission Effective Area Parameters and Initial Downselect	*Mark – 15 min*	*10:50*
Mechanical Layouts and Mass for Final Six	*Jeff – 20 min*	*11:05*
Mirror Design and Performance Summary	*Mark – 10 min*	*11:25*
Trade Summary — Discussion of all Discriminators and Summary Pro's and Con's		
- System Complexity and Performance	*Mark – 15 min*	*11:35*
- Other Discriminators	*Gary – 15 min*	
Lunch break – 15 min break (lunch to be brought in)	*All – 15 min*	*12:05*
Trade Summary (continued)		
- Other Discriminators and Summary	*Gary – 40 min*	*12:20*
Discussion: Final Selection(s) for further study; Wrap-up	*Jean/All – 20 min*	*1:00*
Adjourn		*1:20*

Purpose/Goals of Single Launch Study and Overall Approach

- **Purpose/Goals**
  - Demonstrate potential cost (and possibly schedule) reduction for NASA-only mission on a single launch (compared to Reference of 4 satellites on two Atlas V's) while achieving compelling performance with a low risk implementation

- **How**
  - Perform trades to identify potential implementation concepts using Delta IVH
  - Flesh out single alternate mission concept with goal toward achieving Con-X performance requirements and reducing cost
    - Concept may be eligible for inclusion in next budget submittal (POP-06) if sufficiently understood by Feb 2005

Major Steps to Single Launch Mission Concept Study



Step	Timeframe
1. Define ground rules/trade space	July to mid-August 2005
2. Perform top level trades and studies	August thru October 2005
3. Select mission concept(s)	Oct/Nov 2005
4. Flesh out payload concept	November 2005
5. Flesh out mission concept	December to January 2005
6. Assess cost, schedule, etc.	January to February 2005

- Possible Follow-on Activities:
  - **Configuration trades and optimization**
  - **Performance trades and optimization**
  - **Flesh out alternative option**

Ground Rules and Trade Space for Study

- **The new configuration under study shall**
  - Meet Con-X performance req't's with appropriate design margins
    - Performance Req't's and Goals for this study are defined on later slide
    - Study of Goals will secondary priority to Requirements, much may have to be deferred to after initial mission flesh-out
  - Launch on a single Delta IV Heavy launch vehicle
  - Have an EOB, fixed optical bench or combination of both
  - Utilize following instrument complement:
    - RGS, with off-plane gratings
    - XMS
    - HXT
  - Utilize loop heat pipe control for SXT, as appropriate

Con-X Performance Requirements for NASA-only Single-Launch Study

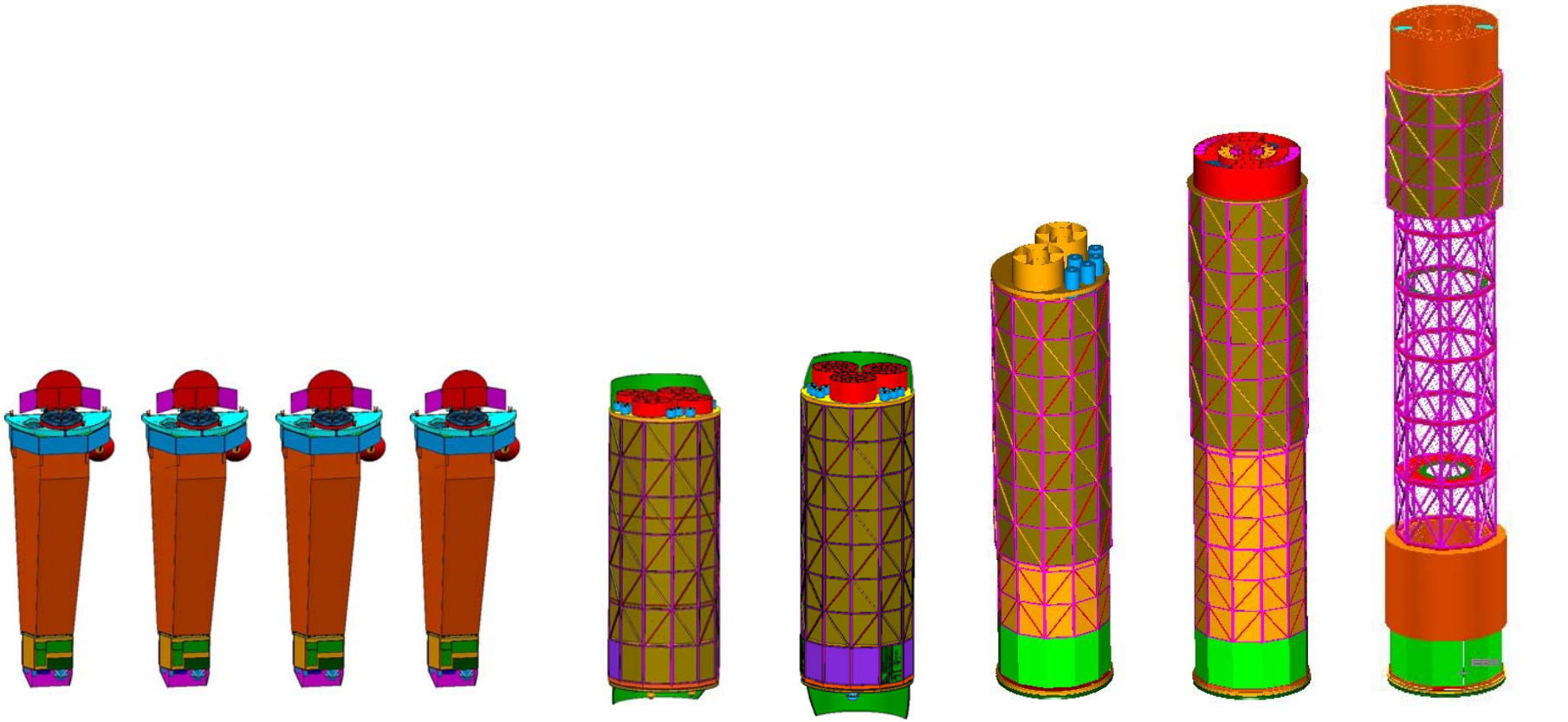
Parameter		Reference Configuration (4 satellites w/10 m focal length)	Single-Launch Concept		Notes
			Req't	Study Goal/Option for Big pay-off	
Energy (keV)		0.25 – 40	Same		
Effective Area (sq cm)	0.25 to 10 keV	1000	Same		
	0.5 keV	1000	Same	2000 (TBR)	For goal, need with R~1200 @ 0.5 keV
	@ 1.25 keV	15,000	Same		
	@ 6.0 keV	6,000	Same	10,000 (TBR)	Any increase above 6000 sq cm is useful
	@ 10 keV	1000	Same		
	@ 40 keV	1500	Same		
Energy Resolution (R)	0.25 - 10 keV	300	Same		
	0.5 keV	300	Same	1200 (TBR)	For goal, need with A~2000 @ 0.5 keV
	@ 6 keV	1500	Same		
	@ 40 keV	10	Same		
Angular Resolution (arc sec HPD)	0.25 to 10 keV	15	Same	10 (TBR)	
	10 to 40 keV	60	Same		
Bright Source Limit (cps/mission)		40,000	TBR		Assume, for now, a filter mechanism can be added for most new cases
FOV (arc min)	<10keV	2.5	Same		
	> 10 keV	8	Same		
Background		TBD	TBR		
Mission Life (years)	Operational Life	4	5		Required life with full effective area
	Consumables	6	Same		
	Prop sizing	6	10 (TBR)		

Ground Rules and Trade Space for Study (cont.)

- **Up for trade for this study**
  - Focal length (10 to 50 m)
  - Number, size and configuration of SXT mirror(s)
  - Orbit (L2 vs LEO) – Closed out early (August ’05)
  - Single or multiple S/C – Emphasized single S/C; mass margins do not seem amenable, at this point, for multiple S/C
  - RGS configuration

- **Not in our trade space for this particular study**
  - International contribution
  - Formation Flying
  - Multiple Launch Vehicles

Reference vs Viable Single Launch Options



4 SXT's w/10 m focal length
packaged into 4 satellites w/ fixed benches

4 SXT's
10 m focal length
Fixed Bench

3 SXT's
11 m focal length
Fixed Bench

2 SXT's
15 m focal length
Deployable Bench

1 SXT
20 m focal length
Deployable Bench

1 SXT
25 m focal length
Deployable Bench

Reference: 2 Atlas V-class launches

"Final Five" Options under Trade for Single Delta IVH launch

Mirror Effective Area Parameters and Initial Downselect

Mark Freeman, SAO

Con-X Mission Configuration Trade Study
October 26, 2005

Effective Area – Principal Science Performance Metric

- Effective Area was selected as the most important metric for SXT design
- To perform unbiased comparisons between mission configurations, we a set of ground rules for doing:
  - SXT designs
  - Effective Area throughput calculations for the gratings and instruments
- These rules allowed multiple mirror designers to develop designs that could be compared

Mirror Design Parameters for Effective Area Calculation

Reflector length:	200 mm	
Mirror thickness:	0.44 mm	Most conservative
Primary/Secondary gap:	50 mm	
Unvignetted FOV (radius):	1.25 arc-min	
Shell mechanical clearance:	0.2 mm minimum	Fixed
Coating:	single layer + binder, Au, 95% density (17.9 gm/cm^2)	Moderate improvements in process should make this achievable
Maximum azimuthal reflector width:	400 mm	Does not affect area calculation
Structural Blockage	12%	R. Petre memo "Correction factors for SXT mirror design" dated 9/15/05
Loss Factors	15%	R. Petre memo, includes edge effects, surface defects, and contamination

Mission Throughput Calculation Parameters

Parameter	Value/Reference Information
Grating Type	Off plane gratings
Angular coverage	*Maximum* two 75 deg wide sectors
Grating module blockage	10% *additional* area reduction on grating area
Grating efficiencies	Per K. Flanagan, Jan '05 PCGrate calculations, de-rated by 0.66, 0.27, and 0.27 respectively (from comparison with synchrotron measurement)
RGA CCD Filter Transmission	100 angstroms Al, LBL optical constants
RGA CCD QE	"Plausible" QE of CCD, supplied by G. Ricker to P. Reid on 01/21/05
Grating resolution	Provided by K Flanagan 01/21/05 for OPG.
XMS efficiencies	Provided by Rich Kelley for FMA study
XMS filter transmission	MDF Kevlar Filter, reviewed by R. Kelley Jan. 05
XMS resolution	Assume 2eV FWHM resolution at low E

Throughput Factor Summary

Energy	Grating Throughput	XMS Throughput
0.25 keV	0.153	0.00
1.25 keV	0.045	0.627
6.0 keV	0.00	0.709

- Applies all throughput factors listed on previous page
- Includes resolution cutoff (R > 300) for gratings and XMS
- XMS throughput includes acceptance of *all event grades*
- Grating throughput factor is applied only to the area of the telescope covered by grating modules

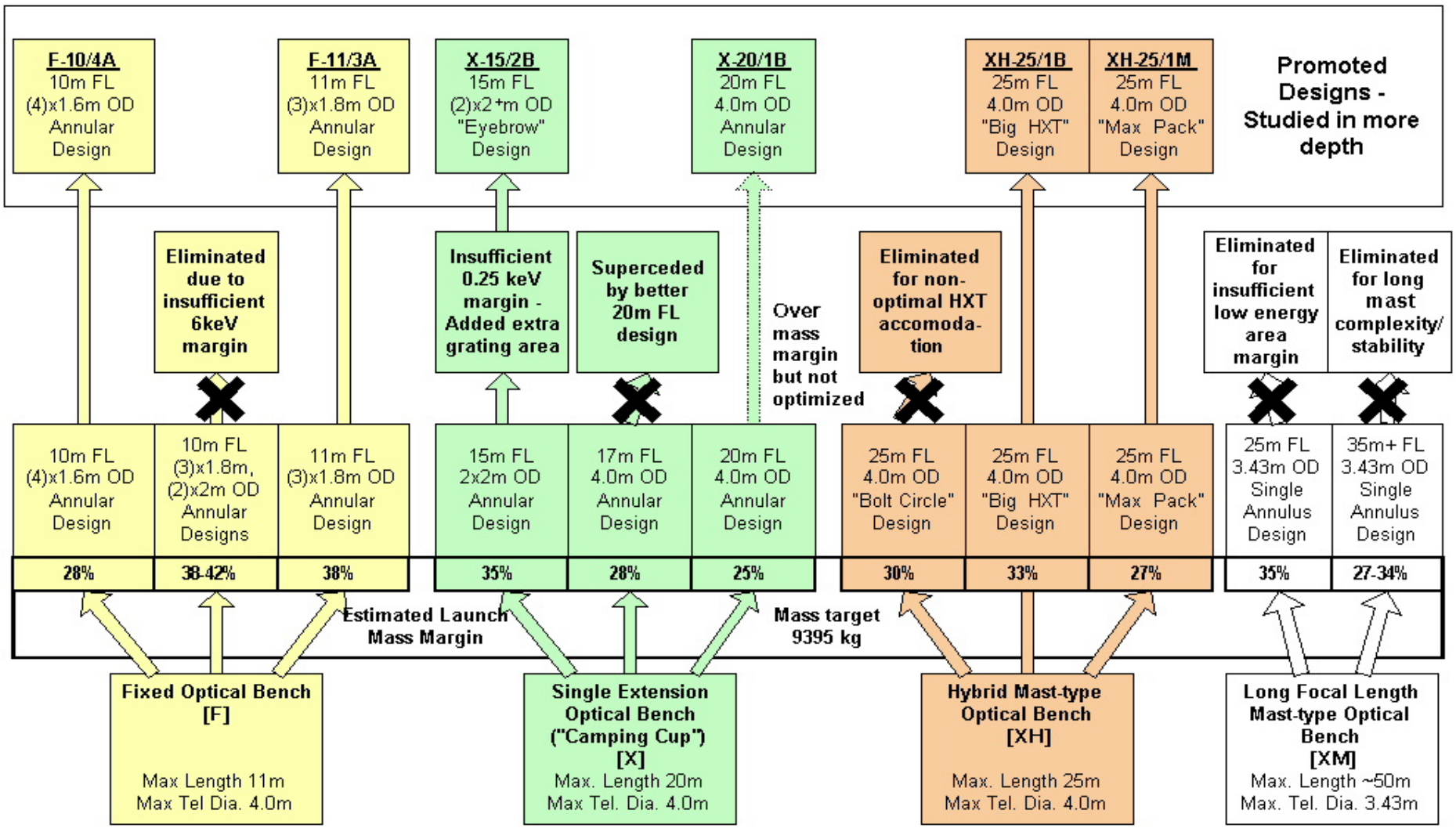
Basis for the Initial Downselect

- **Design for a single Delta IV – H (heavy) launch**
  - **Use the 19m metallic fairing (truss PAF allows for high center-of-gravity)**
  - Launch mass **allowance for direct insertion to L2**
- **Maximize "performance" for a mission that fits within this envelope (roughly 4m dia., 11m long)**
  - **Primary performance parameter used for evaluation is** Effective Area (@ 0.25, 1.25, and 6.0 keV)

Flow of the Selection Process

- **Originally considered were designs ranging from 50m focal length (using a mast-type optical bench) to a repackaging of the (4) 1.6m telescopes in a single fixed bench.**
- **J. Stewart developed more than 15 configurations that limited mirror size and/or area on the mirror platform for a number of options spanning this range**
- **A few were eliminated quickly as untenable or offering no improvement over another listed design**
- **Mirror designs and multi-SXT layouts were generated for the viable candidate design configurations by** Will Zhang **and** Paul Reid**.**
- **Effective Area (uniformly applying the throughput factors) were generated for candidate designs**

Downselect Tree



Mechanical Layouts and Mass for Final Six

Jeff Stewart

Con-X Mission Configuration Trade Study
October 26, 2005

Mass Summary: All Configurations

ITEM	Mass (kg)																		
Configuration	For Reference Only			XM-10/3/1.54	F-10/4/1.6A	XM-10/2/1.71	F-10/2/2	F-11/3/1.8A	XM-15/2/1.71	X-15/2/2A	XM-17/1/3.43	X-17/1/4	X-20/1/4	XM-25/1/3.43	XH-25/1/4A	XH-25/1/4B	XH-25/1/4M	XM-35/1/3.43	XM-50/1/3.43
	Reference Baseline (single)	Reference Baseline (total)	FF NASA-only	EOB (Mast Type)	Fixed Bench	EOB (Mast Type)	Fixed Bench	Fixed Bench	EOB (Mast Type)	EOB (1-EXT Type)	EOB (Mast Type)	EOB (1-EXT Type)	EOB (1-EXT Type)	EOB (Mast Type)	EOB (Hybrid)	EOB (Hybrid)	EOB (Hybrid)	EOB (Mast Type)	EOB (Mast Type)
Type of Bench	Fixed	Fixed	FF	Deploy	Fixed	Deploy	Fixed	Fixed	Deploy	Deploy	Deploy	Deploy	Deploy	Deploy	Deploy	Deploy	Deploy	Deploy	Deploy
Focal Length (meters)	10	10	50	10	10	10	10	11	15	15	17	17	20	25	25	25	25	35	50
SXT Diameter (meters)	1.6	1.6	4	1.54	1.6	1.71	2	1.8	1.71	2	3.43	4	4	3.43	4	4	4	3.43	3.43
SXT # of Degrees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HXT Diameter (meters)	0.4	0.4	1	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.55	0.55	0.55	0.74	0.74	0.74	0.74	0.7	1
# of HXTs	3	12	1	12	12	12	12	12	5	5	4	4	4	2	2	2	2	2	1
Number of Grating Modules	100	400	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Number of Satellites	1	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Number of Launch Vehicles	0	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Number of Telescopes per Spacecraft	1	1	1	3	4	2	2	3	2	2	1	1	1	1	1	1	1	1	1
Launch Vehicle	n/a	Atlas V	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy
Instruments	1043	4172	4123	3724	3774	2967	2949	3492	3751	3152	3720	4005	4001	3821	4098	3822	4395	3832	4096
SXT/FMA	642	2569	3365	2363	2303	1798	1835	2186	2492	1835	2495	2872	2872	2495	2714	2438	3011	2495	2495
Reflectors	205	820			963		888	970	1057	888	1057	1142	1142	1057	984	859	1281	1057	1057
X-Ray Microcalorimeter Spectrometer (XMS)	147	588	276	441	588	294	294	441	310	310	158	158	158	170	170	170	170	203	276
RGS	98	394	196	461	461	461	461	460	455	455	453	453	449	443	443	443	443	430	411
RGA	73	294	146	361	361	361	361	361	361	361	361	361	361	361	361	361	361	361	361
RGS Focal Plane Camera (RFC)	25	100	50	100	100	100	100	99	94	94	91	91	88	81	81	81	81	69	50
HXT	151	604	286	398	415	353	353	398	405	405	514	514	514	462	524	524	524	494	618
Hard X-Ray Telescope (HXT) Mirror	99	396	286	207	207	207	207	207	203	203	260	260	260	254	254	254	254	234	260
Hard X-Ray Telescope (HXT) Detector	52	208	0	191	208	146	146	191	202	202	254	254	254	208	270	270	270	260	358
Structure	682	2726	712	718	1403	718	1191	1524	763	1545	879	1500	1747	914	1151	1151	1151	942	1077
Thermal	47	188	210	252	294	224	236	269	229	240	227	241	241	234	246	246	246	254	284
Harness	126	504	0	154	162	150	150	154	176	166	210	201	201	220	220	220	220	240	270
Mechanisms	59	236	0	213	276	150	150	213	150	277	87	87	87	87	87	87	87	87	87
S/C Subsystem Components	300	1199	684	373	399	347	347	375	361	361	345	346	357	387	387	387	387	464	612
Launch Vehicle Interfaces	63	252	43	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Separation System	63	252	0	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
TOTAL DRY MASS	2319	9277	5772	5632	6505	4753	5221	6225	5627	5939	5666	6578	6833	5861	6387	6111	6684	6017	6624
Propellant	180	720	873	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214
TOTAL WET MASS	2499	9997	6645	5846	6719	4966	5435	6439	5840	6152	5880	6791	7046	6075	6601	6325	6898	6230	6838
Contingency/Reserve	n/a	2999	2750	3549	2676	4429	3960	2956	3555	3243	3515	2604	2349	3320	2794	3070	2497	3165	2557
(% LV) Performance	n/a	23%	29%	38%	28%	47%	42%	31%	38%	35%	37%	28%	25%	35%	30%	33%	27%	34%	27%
Launch Vehicle Performance	n/a	12996	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395	9395
Mass Margin Against 30% Contingency	n/a	-900	-69	730	-143	1610	1142	137	736	424	696	-215	-470	502	-25	251	-322	346	-261

Mass Summary: Down-Selected Configurations

ITEM	Mass (kg)							
Configuration	For Reference Only		F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4	XH-25/1/4B	XH-25/1/4M
	Reference Baseline (single)	Reference Baseline (total)	Fixed Bench	Fixed Bench	EOB (1-EXT Type)	EOB (1-EXT Type)	EOB (Hybrid)	EOB (Hybrid)
Type of Bench	Fixed	Fixed	Fixed	Fixed	Deploy	Deploy	Deploy	Deploy
Focal Length (meters)	10	10	10	11	15	20	25	25
SXT Diameter (meters)	1.6	1.6	1.6	1.8	2	4	4	4
SXT # of Degrees	0	0	0	0	0	0	0	0
HXT Diameter (meters)	0.4	0.4	0.4	0.4	0.6	0.55	0.74	0.74
# of HXTs	3	12	12	12	5	4	2	2
Number of Grating Modules	100	400	225	225	225	225	225	225
Number of Satellites	1	4	1	1	1	1	1	1
Number of Launch Vehicles	0	2	1	1	1	1	1	1
Number of Telescopes per Spacecraft	1	1	4	3	2	1	1	1
Launch Vehicle	n/a	Atlas V	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy	Delta IV Heavy
Instruments	1043	4172	3774	3492	3152	4001	3822	4395
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RGA	73	294	361	361	361	361	361	361
RGS Focal Plane Camera (RFC)	25	100	100	99	94	88	81	81
HXT	151	604	415	398	405	514	524	524
Hard X-Ray Telescope (HXT) Mirror	99	396	207	207	203	260	254	254
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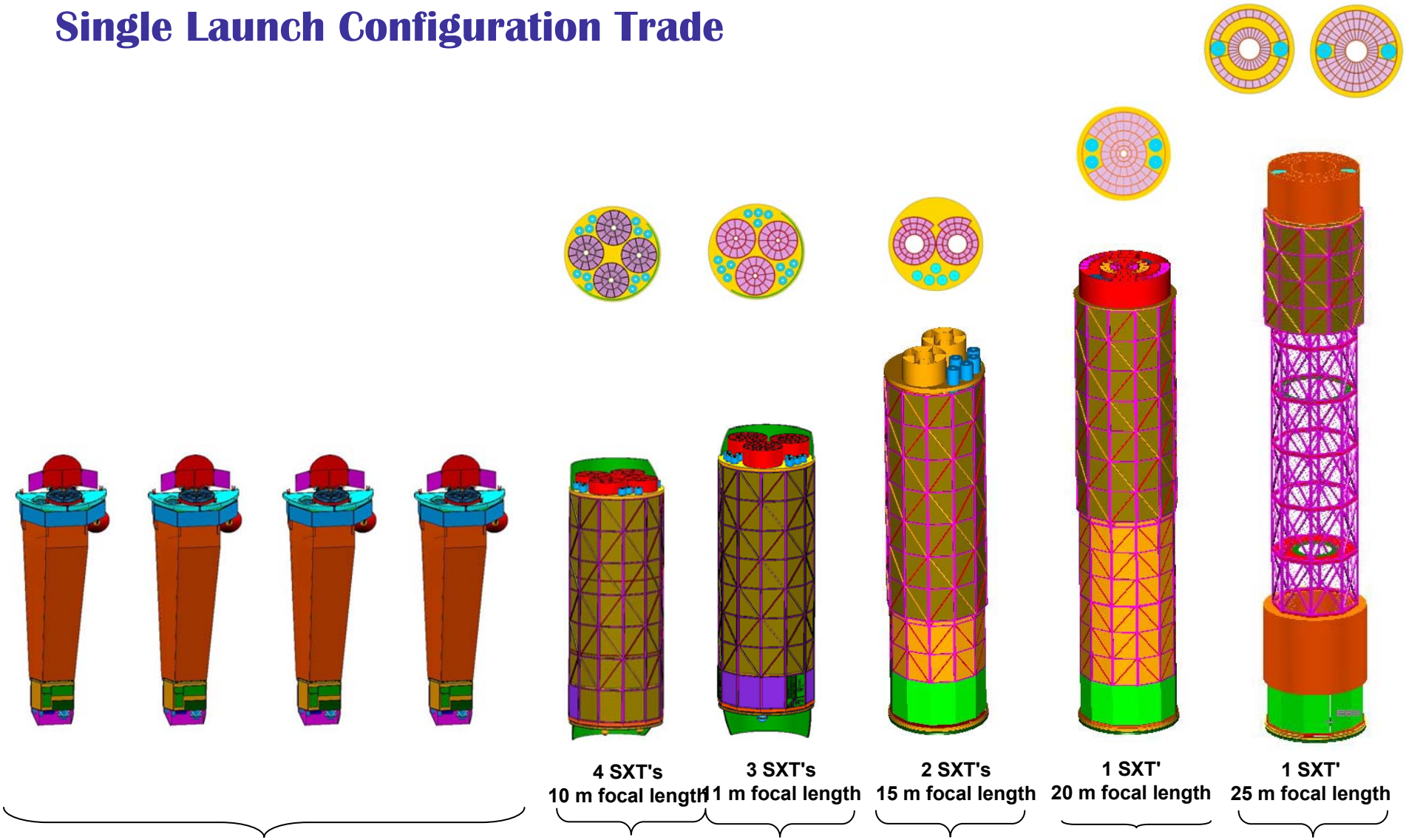
Structure	682	2726	1403	1524	1545	1747	1151	1151
Thermal	47	188	294	269	240	241	246	246
Harness	126	504	162	154	166	201	220	220
Mechanisms	59	236	276	213	277	87	87	87
S/C Subsystem Components	300	1199	399	375	361	357	387	387
Launch Vehicle Interfaces	63	252	198	198	198	198	198	198
Separation System	63	252	198	198	198	198	198	198
TOTAL DRY MASS	2319	9277	6505	6225	5939	6833	6111	6684
Propellant	180	720	214	214	214	214	214	214
TOTAL WET MASS	2499	9997	6719	6439	6152	7046	6325	6898
Contingency/Reserve	*n/a*	2999	2676	2956	3243	2349	3070	2497
(% LV) Performance	*n/a*	23%	28%	31%	35%	25%	33%	27%
Launch Vehicle Performance	*n/a*	*12996*	*9395*	*9395*	*9395*	*9395*	*9395*	*9395*
Mass Margin Against 30% Contingency	*n/a*	*-900*	*-143*	*137*	*424*	*-470*	*251*	*-322*

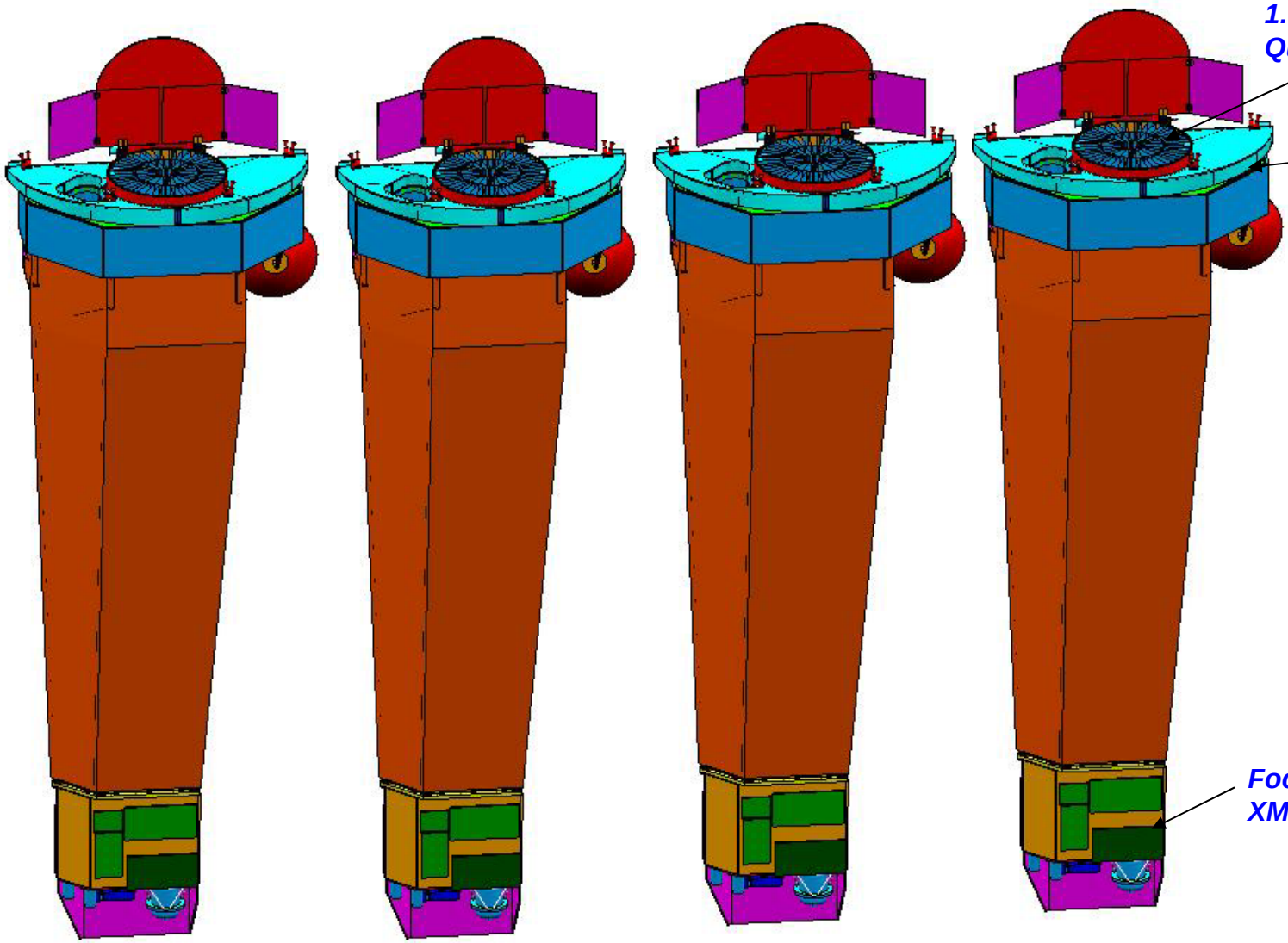
Single Launch Configuration Trade



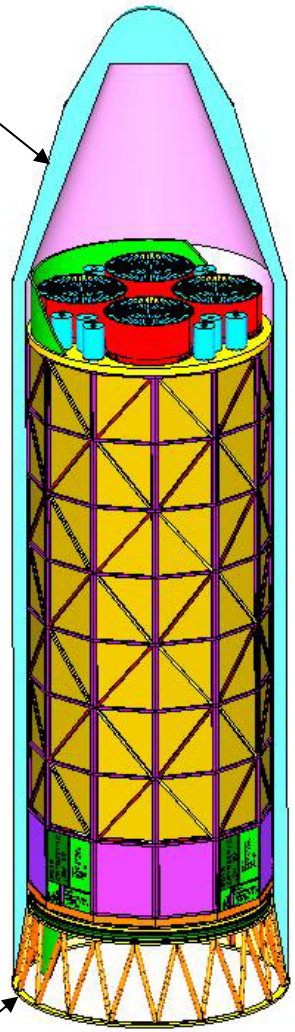
Reference: 2 Atlas V-class launches

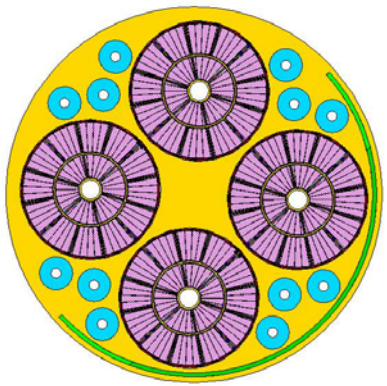
Optics under Trade for single Delta IVH launch

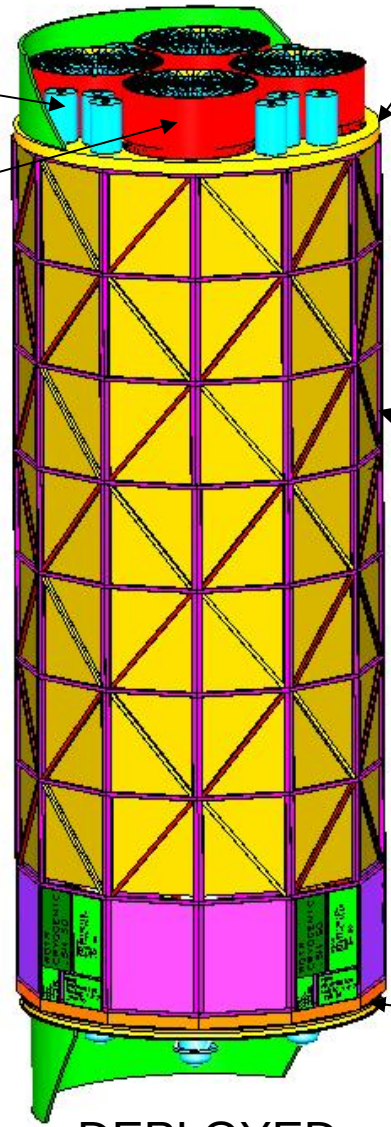
Reference Design: 10 Meter Focal Length



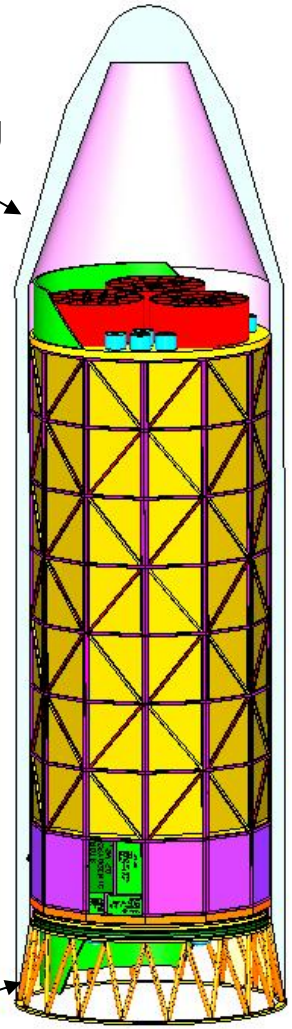
Configuration: F-10/4/1.6A







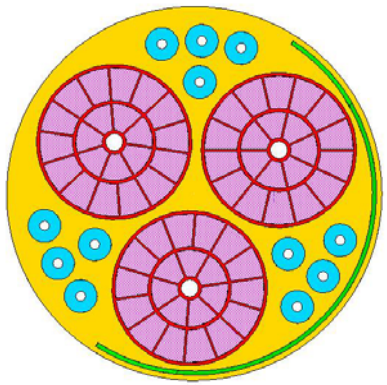
Configuration: F-11/3/1.8A



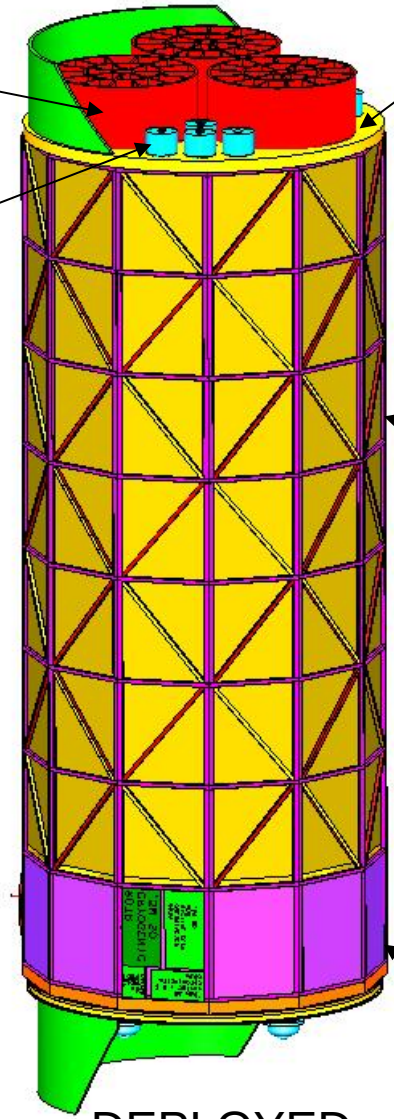
STOWED

SXT Mirror (1.8 m dia.)
Quantity=3

HXT Mirror (0.4 m dia.)
Quantity=12



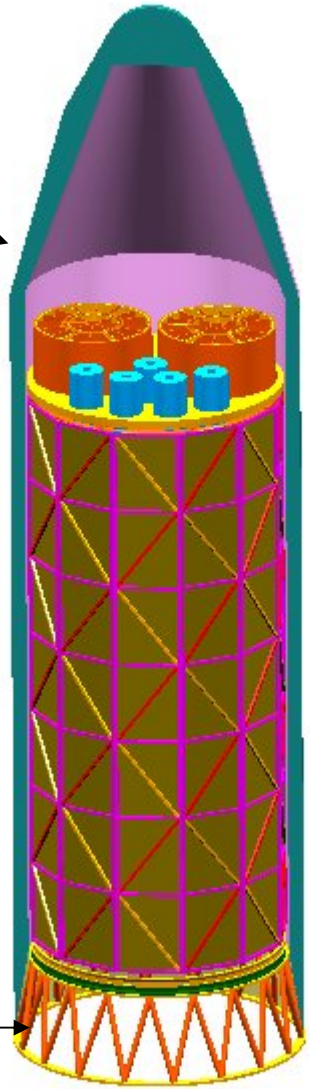
Mirror Cross-Section



DEPLOYED

Configuration: X-15/2/2A

Delta IV
19.8 Meter
Metallic Fairing

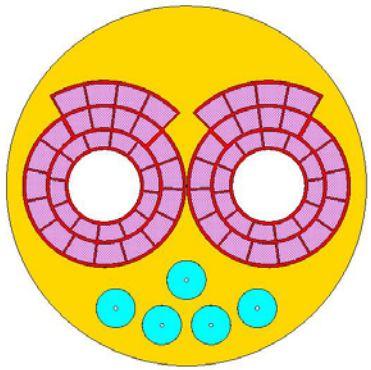


Delta IV 4394 PAF

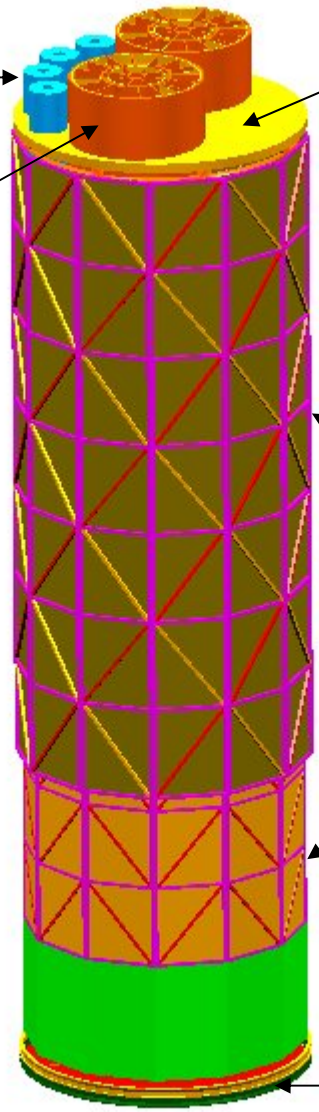
STOWED

HXT Mirror (0.6 m dia.)
Quantity=5

SXT Mirror (2 m dia.)
Quantity=2



Mirror Cross-Section



SXT and HXT Mirror Bench

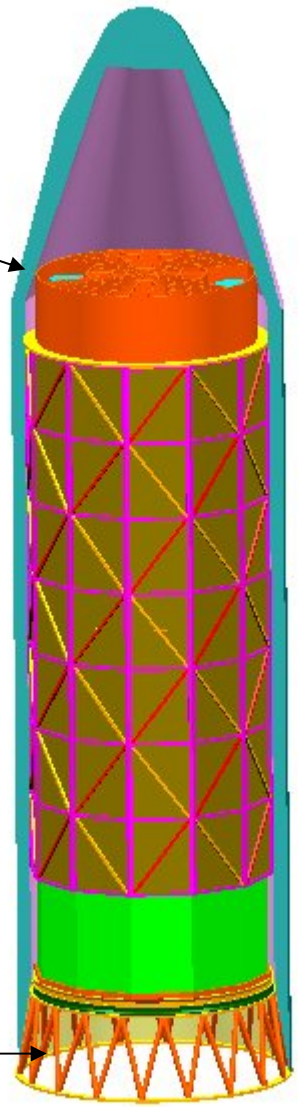
Fixed Truss

Deployable Truss

SXT-HXT-RFC Detector Bench and S/C Bus

DEPLOYED

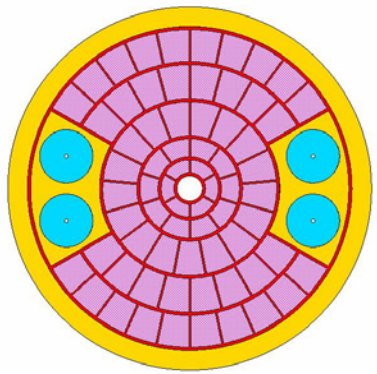
Configuration: X-20/1/4



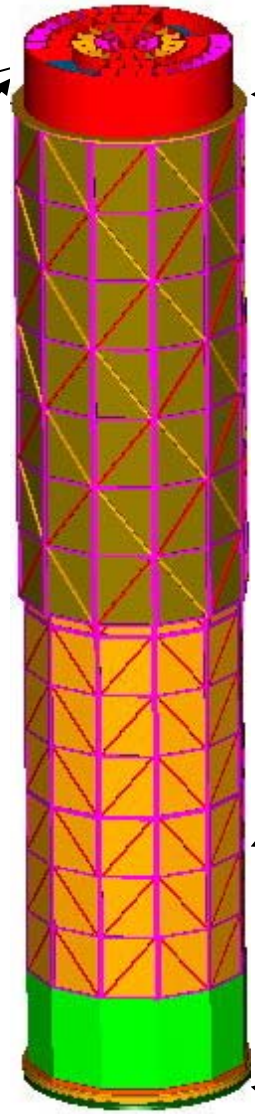
STOWED

HXT Mirror (0.67 m dia.)
Quantity=4

SXT Mirror (4 m dia.)
Quantity=1

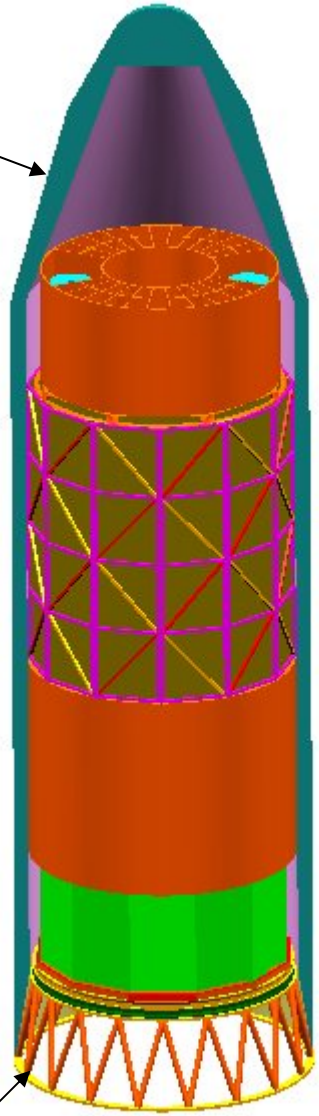


Mirror Cross-Section



DEPLOYED

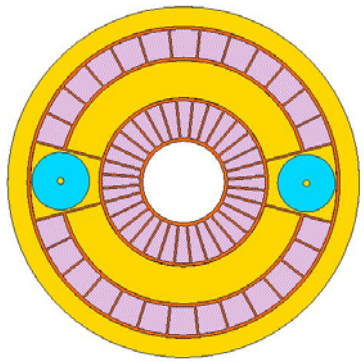
Configuration: XH-25/1/4B



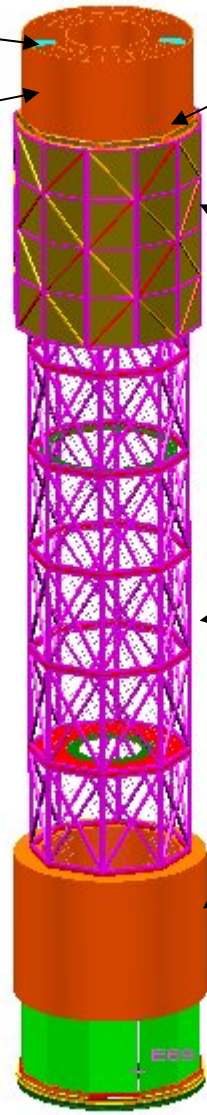
STOWED

HXT Mirror (0.74 m dia.)
Quantity=2

SXT Mirror (4 m dia.)
Quantity=1

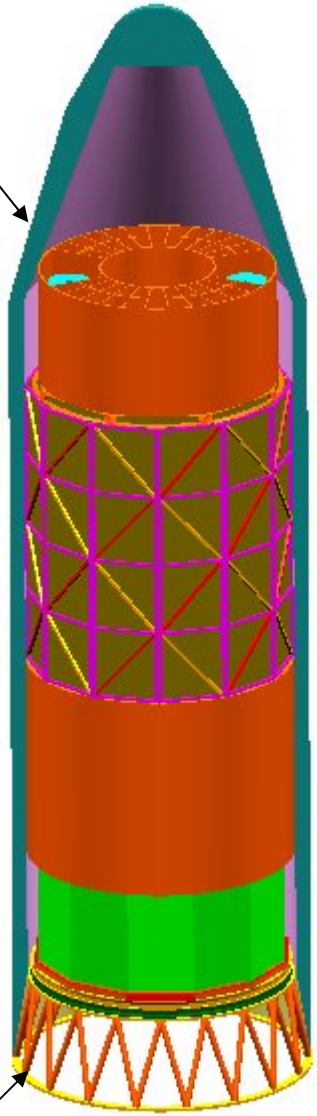


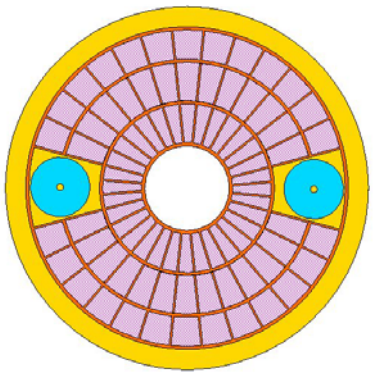
Mirror Cross-Section

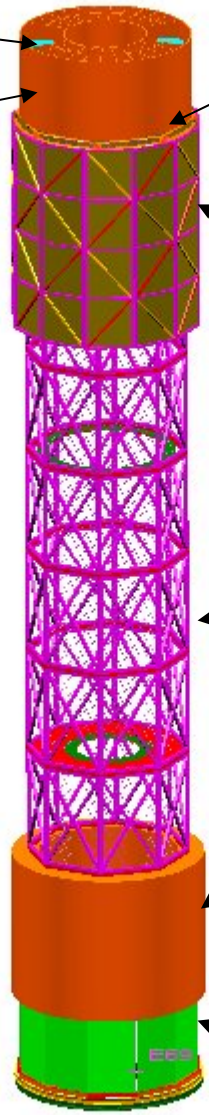


DEPLOYED

Configuration: XH-25/1/4M







Mirror Design and Performance Summary

Mark Freeman

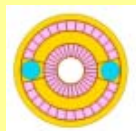
Con-X Mission Configuration Trade Study
October 26, 2005

Facts about the Selected Mirror Designs

- **All the SXT designs downselected have a small range of F-number**
  - **Represents an "optimum" for balancing selected energies**
- **All the HXT designs have been scaled similarly for best weight and "concentration factor"**
  - **"Optimum" F-number for performance ~66**

Design	**Reference F-10/4A**	**F11/3A**	**X-15/2B**	**X-20/1B**	**X-25/1B X-25/1M**
SXT F-number	**12.5**	**12.2**	**11.5**	**10.0**	**12.5**
HXT number/ diameter	**(12) 0.3m**	**(12) 0.3m**	**(5) 0.45m**	**(3-4) 0.6m**	**(2) 0.75m**

Mirror Design/Effective Area

Design Parameters	Name*	Reference w/ Off-plane	F-10/4A	F-11/3A	X-15/2B	X-20/1B	XH-25/1B	XH-25/1B-M
Description		4 Spacecraft	IV	III	One-sided	Ib	2 big HXTs	2 big HXTs; max pack
Cross sectional view		n/a						
Focal Length (m)		10	10	11	15	20	25	25
Number of SXT's per mission		4	4	3	2	1	1	1
Mirror Outer Annulus OD (m)		1.61	1.60	1.80	2+*	4.00	4.00	4.00
Mirror Outer Annulus ID (m)		0.92	1.18	1.34	1.48	3.12	3.20	3.15
Mirror Inner Annulus ID (m)		0.30	0.30	0.20	0.50	0.40	1.13	1.17
Angular span of gratings		150	150	150	75	150	150	150
Angular accomodation for HXTs		0	0	0	0	120	62	62
# of shell sizes		216	216	298	339	602	308	391
Estimated # of mandrels		432	432	596	678	1204	524	782
Reflector Mass (kg)		987	963	970	929	1142	859	1281
FMA mass (kg, estimated)		2396.60	2338	2355	2256	2773	2086	3110
FMA mass to Reference mass		1.00	0.98	0.98	0.94	1.16	0.87	1.30
Mirror Area to RGS	0.25 keV	12440	8015	7337	8118	9763	10100	10854
	1.25 keV	11870	7587	6925	7692	8912	9550	10260
	6 keV	508	24	15	137	3	16	19
	10 keV	1	0	0	0	0	0	0
Mirror Area to XMS	0.25 keV	27850	29753	29500	27583	36310	24830	45677
	1.25 keV	26900	28765	28509	26843	34882	24010	44188
	6 keV	8130	9773	9650	10071	10648	9790	12587
	10 keV	3310	3488	3904	3439	4222	2680	2442
Total Mission EA	**0.25 keV**	**1906**	**1228**	**1124**	**1244**	**1496**	**1548**	**1663**
	1.25 keV	**17402**	**18377**	**18187**	**17176**	**22272**	**15485**	**28168**
	6 keV	**5763**	**6927**	**6840**	**7101**	**7547**	**6939**	**8922**
	10 keV	**1996**	**2103**	**2354**	**1741**	**2546**	**1616**	**1473**
Margin to Mission Requirement	**0.25 keV**	**91%**	**23%**	**12%**	**24%**	**50%**	**55%**	**66%**
	1.25 keV	**16%**	**23%**	**21%**	**15%**	**48%**	**3%**	**88%**
	6 keV	**-4%**	**15%**	**14%**	**18%**	**26%**	**16%**	**49%**
	10 keV	**100%**	**110%**	**135%**	**74%**	**155%**	**62%**	**47%**

Trade Summary — System Complexity and Performance

Mark Freeman

Con-X Mission Configuration Trade Study
October 26, 2005

Configuration Trade Summary

- PERFORMANCE
  - Effective Area Margin
  - Time to complete TRIP science program
  - Signal / Noise Figure of Merit
  - Signal / Background Figure of Merit
- REDUNDANCY
- OTHER FACTORS (PROXY FOR COST & SCHEDULE)
  - System Mass Margin
  - Complexity
    - System Complexity
    - Instrument Complexities
      - » XMS
      - » RGS
      - » HXT
  - Technical Risk Factors
    - Optical Bench Factors
    - SXT Manufacturability
    - Detector Calibration
    - System Testing Issues
  - Testability
  - Program Risk Factors
- Summary

Format of Trade Worksheet

Configuration:

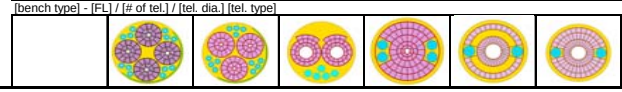
Trade parameters

Merit Function

Score

Score Definition

Proposed Selection Criteria

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID Naming Convention:	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/A	XH-25/1/4B	XH-25/1/4M	Weighting	Factor
	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
HXT									
# Detectors	12	12	12	5	4	2	2	Low	1
Relative Focal Plane Size (area w.r.t. reference)	1.0	1.0	1.0	2.3	4.0	6.3	6.3	Low	1
Relative # mandrels	1.0	1.0	1.0	1.5	1.4	1.9	1.9	Medium	2
HXT Complexity Merit, lower is better	15	15	15	10	11	12	12		
Rank (Merit Function), 1 = best	5	5	5	1	2	3	3		
Score	-	-	-	+	+	+	+		

+	0	-
Less complex	Average	More complex

Merit Function Definitions

System Complexity

- **Focal plane layout complexity: Basis is simply the number of detectors.**
  - Range from 20 to 4 – serves as basis for other factor ranges
  - Large value = limited options for layout of RGS detector
- **SXT Alignment/Assembly complexity: basis is the number of modules that need to be assembled and aligned**
  - Divided by 3 for reasonable scaling with # detectors
- **Thermal control complexity largely a function of detector requirements**
  - Separate dewars for 4 XMS (solar shading, views to each other)
  - Balancing available "real estate" on detector bench and in electronics section for the needs of up to 20 detectors of 3 types into control zones
  - Basis is simply the number of zones on detector bench

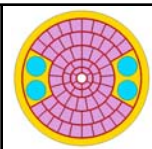
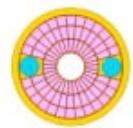
System Complexity (cont'd)

- **Optical bench complexity:**
  - Fixed – simple
  - Single extension "Camping cup" - moderate
  - Hybrid (with mast, "sock") – complicated
  - Use 3^n scaling (1 – simple, 3 – moderate, 9 – complicated)
- **Co-alignment: Multiple telescopes must be boresighted**
  - Basis is (# SXT telescopes –1) + (# HXT tel. – 1)/2
- **Fidlight system:**
  - Assumed not needed for fixed bench (1.0)
  - Might be needed for 15m (2.0)
  - Probably needed for 25m mast configurations (3.0)
- **Telescope thermal control: Difficult problem is at the module level; since that needs to be solved only once per module design, not a big discriminator**

System Complexity (cont'd)

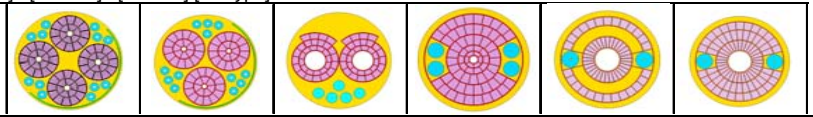
- **Science and Mission Ops Complexities**
  - In-flight Operations – more complex to handle commanding and basic operations with multiple satellites.
    - Basis is number of satellites
  - Science Co-addition of Data – more complex with multiple instruments (calibration, etc.).
    - Basis is (number of SXT instruments co-added – 1).
    - One additional point is charged to the Reference design for the addition complexity of photon arrival timing on 4 satellites

System Complexity

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope		
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2B	X-20/1/4B	XH-25/1/4B	XH-25/1/4M
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]						
Telescope Layout							
System Complexity Assessment							
System complexity factors							
Total Number of Launches	2	1	1	1	1	1	1
Total Number of Satellites	4	1	1	1	1	1	1
Total Number of Detectors	20	20	18	9	6	4	4
System Complexity Parameters							
SXT assy/alignment (# modules/3)	6.0	24.0	21.0	21.3	23.0	14.3	23.0
Optical bench	1.0	1.0	1.0	3.0	3.0	9.0	9.0
Thermal Control (# discrete zones in FP)	3.0	12.0	9.0	5.0	4.0	4.0	4.0
Telescope co-alignment (# co-alignments)	1.0	11.5	9.5	4.5	1.5	0.5	0.5
Fidlight System Need (15" res) liklihood	1.0	1.0	1.0	2.0	2.0	3.0	3.0
Thermal Control (telescopes)	1.0	2.0	2.0	2.0	2.0	2.0	2.0
In-Flight Operational/Software	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Science co-adding of data (#SXTs - 1)	1.0	3.0	2.0	1.0	0.0	0.0	0.0
Merit Function (# detectors + parameters * #satellites)	80.0	75.5	64.5	48.8	42.5	37.8	46.5

System Performance & Science Time

Proposed Selection Criteria

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/A	XH-25/1/4B	XH-25/1/4M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
System Performance								Requirement	
Effective Area Margin									
@ 0.25 keV	91%	23%	12%	24%	50%	55%	66%	1000	cm^2
@ 1.25 keV	16%	23%	21%	15%	48%	3%	88%	15000	cm^2
@ 6.0 keV	-4%	15%	14%	18%	26%	16%	49%	6000	cm^2
@ 10.0 keV	100%	110%	135%	74%	155%	62%	47%	1000	cm^2
Average margin, (0.25, 1.25, & 6.0 keV)	34%	20%	16%	19%	41%	25%	68%		
Score	+	0	-	-	+	0	+		

Note: 0.25 keV and 1.25 keV areas can be rebalanced

Mission time to complete TRIP science							
Time to complete TRIP science program, Msec	107	113	116	117	100	118	83
Merit Function (Time Margin (relative to 4 year mission))	15%	10%	7%	7%	20%	6%	34%
Score	0	0	-	-	0	-	+

System Performance

+	0	-

Relative to the baseline

>	Baseline	<

Mission time to complete TRIP science

+	0	-

Margin

> 25%	> 10%	

Trade Summary — Other Discriminators

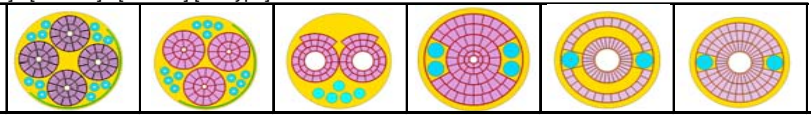
Gary Sneiderman

Configuration Trade Summary

- PERFORMANCE
  - Effective Area Margin
  - Time to complete TRIP science program
  - Signal / Noise Figure of Merit
  - Signal / Background Figure of Merit
- REDUNDANCY
- OTHER FACTORS (PROXY FOR COST & SCHEDULE)
  - System Mass Margin
  - Complexity
    - System Complexity
    - Instrument Complexities
      - » XMS
      - » RGS
      - » HXT
  - Technical Risk Factors
    - Optical Bench Factors
    - SXT Manufacturability
    - Detector Calibration
    - System Testing Issues
  - Testability
  - Program Risk Factors
- Summary

System Performance & Science Time

Proposed Selection Criteria

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/A	XH-25/1/4B	XH-25/1/4M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
System Performance								Requirement	
Effective Area Margin									
@ 0.25 keV	91%	23%	12%	24%	50%	55%	66%	1000	cm^2
@ 1.25 keV	16%	23%	21%	15%	48%	3%	88%	15000	cm^2
@ 6.0 keV	-4%	15%	14%	18%	26%	16%	49%	6000	cm^2
@ 10.0 keV	100%	110%	135%	74%	155%	62%	47%	1000	cm^2
Average margin, (0.25, 1.25, & 6.0 keV)	34%	20%	16%	19%	41%	25%	68%		
Score	+	0	-	-	+	0	+		

Note: 0.25 keV and 1.25 keV areas can be rebalanced
Note: XMS filter thickness will change 1.25keV EA

Mission time to complete TRIP science							
Time to complete TRIP science program, Msec	107	113	116	117	100	118	83
Merit Function (Time Margin (relative to 4 year mission))	15%	10%	7%	7%	20%	6%	34%
Score	0	0	-	-	0	-	+

System Performance

+	0	-

Margin Greater than:

30%	20%	

Mission time to complete TRIP science

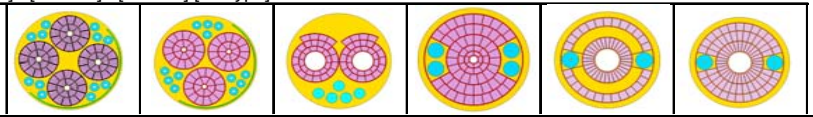
+	0	-

Margin

> 25%	> 10%	

System Performance Figures of Merit

Proposed Selection Criteria

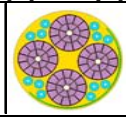
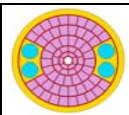
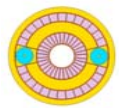
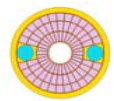
Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/A	XH-25/1/4B	XH-25/1/4M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
Performance Figures of Merit (assumes = Angular Resolution)									
Signal to Noise : 10*SQRT(S(EA1.25keV /# SXT's/FL)^2)									
Signal to Noise Merit, higher is better	0.87	0.92	0.95	0.81	1.11	0.62	1.13		
Score	0	+	+	-	+	-	+		
Signal to Background : 10*SQRT(S(EA1.25keV /# SXT's/FL^2)^2)									
Signal to Background Merit, higher is better	0.087	0.092	0.087	0.054	0.056	0.025	0.045		
Score	0	+	0	-	-	-	-		

+	0	-

Relative to the baseline

>	Baseline	<

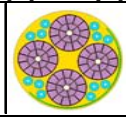
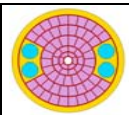
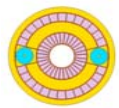
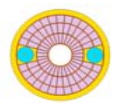
Redundancy

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope			Weighting	Factor
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/B	XH-25/1/4B	XH-25/1/4B-M		
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
Inherent Redundancy, % Mission Loss									
Launches	50%	100%	100%	100%	100%	100%	100%		
Satellites	25%	100%	100%	100%	100%	100%	100%		
Instruments									
HXTs	8%	8%	8%	20%	25%	50%	50%		
RGSs	25%	25%	33%	50%	100%	100%	100%		
XMSs	25%	25%	33%	50%	100%	100%	100%		
Inherent Redundancy Merit, lower is better	1.33	2.58	2.75	3.20	4.25	4.50	4.50		
Score	+	+	+	0	-	-	-		

Inherent Redundancy

+	0	-
Robust	Some	Minimal

Mass Margin

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/B	XH-25/1/4B	XH-25/1/4B-M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									

System Mass Margin

System Mass Margin	23%	28%	31%	34%	24%	31%	25%
Score	-	0	+	+	-	+	0

Mass

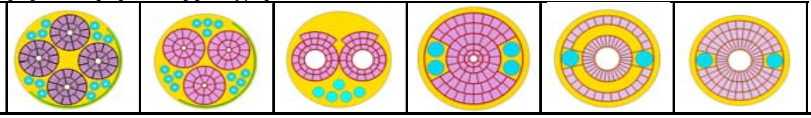
+	0	-

Margin Greater than:

30%	25%	

System Complexity

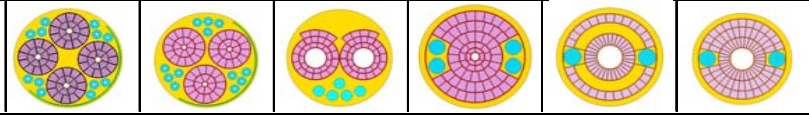
Proposed Selection Criteria

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/A	XH-25/1/4B	XH-25/1/4M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
System Complexity Assessment									
System complexity factors									
Total Number of Launches	2	1	1	1	1	1	1		
Total Number of Satellites	4	1	1	1	1	1	1		
Total Number of Detectors	8	8	6	4	2	2	2		
System Complexity Parameters									
SXT assy/alignment (# modules/3)	6.0	24.0	21.0	21.3	23.0	14.3	23.0		
Optical bench	1.0	1.0	1.0	3.0	3.0	9.0	9.0		
Thermal Control (# discrete zones in FP)	3.0	12.0	9.0	5.0	4.0	4.0	4.0		
Telescope co-alignment (# co-alignments)	1.0	11.5	9.5	4.5	1.5	0.5	0.5		
Fidlight System Need (15" res) liklihood	1.0	1.0	1.0	2.0	2.0	3.0	3.0		
Thermal Control (telescopes)	1.0	2.0	2.0	2.0	2.0	2.0	2.0		
In-Flight Operational/Software	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Science co-adding of data (#SXTs - 1)	1.0	3.0	2.0	1.0	0.0	0.0	0.0		
Merit Function (# detectors + parameters * #satellites)	68.0	63.5	52.5	43.8	38.5	35.8	44.5		
Score	-	-	-	0	+	+	0		

System Complexity

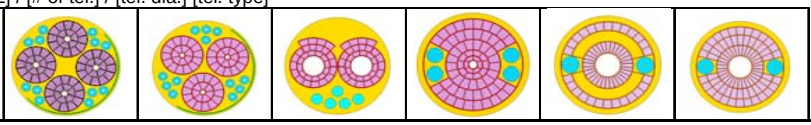
+	0	-
Less complex	Average	More complex

Instrument Complexity Factors

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope				
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/B	XH-25/1/4B	XH-25/1/4B-M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
XMS									
# detectors	4	4	3	2	1	1	1	Low	1
Relative Focal Plane Size (area w.r.t. reference)	1.0	1.0	1.0	2.3	4.0	6.3	6.3	High	3
Relative # Pixels/detector	1.0	1.0	1.2	2.3	4.0	6.3	6.3	High	3
Relative Filter Size	1.0	1.0	1.0	1.5	2.0	2.5	2.5	Medium	2
XMS Complexity Merit, lower is better	12	12	12	19	29	44	44		
Score	+	+	+	0	-	-	-		
RGS									
Relative # Grating Modules	1.0	0.7	0.6	0.7	0.9	0.8	0.9	Low	1
Pathlength accommodation (curved gratings)	1	1	1	0	1	1	1	Low	1
# RFCs	4	4	3	2	1	1	1	Low	1
Relative # CCDs / RFC	1.0	1.0	1.1	1.4	1.9	2.3	2.3	Low	1
RGS Complexity Merit, lower is better	7.0	6.7	5.7	4.1	4.8	5.1	5.2		
Score	-	-	0	+	+	+	+		
HXT									
# Detectors	12	12	12	5	4	2	2	Low	1
Relative Focal Plane Size (area w.r.t. reference)	1.0	1.0	1.0	2.3	4.0	6.3	6.3	Low	1
Relative # mandrels	1.0	1.0	1.0	1.5	1.4	1.9	1.9	Medium	2
HXT Complexity Merit, lower is better	15	15	15	10	11	12	12		
Score	-	-	-	+	+	+	+		

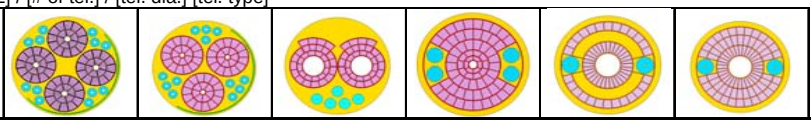
+	0	-
Less complex	Average	More complex

Technical Risk Factors

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope			
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/B	XH-25/1/4B	XH-25/1/4B-M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
Optical Bench Factors									
Bench Deployment (flight performance)	n/a	n/a	n/a	lower	lower	higher	higher	Lower = 1	
Ability to keep light tight	lower	lower	lower	medium	medium	higher	higher	Medium = 2	
Bench Deployment Development	lower	lower	lower	medium	medium	higher	higher	Higher = 3	
Optical Bench Merit, lower is better	2	2	2	5	5	9	9		
Score	+	+	+	0	0	-	-		
SXT manufacturability									
Extent to which size complicates fabrication/assembly	1	1	1	3	5	5	5	Lower = 1	
Handling complexity	1	1	1	3	5	5	5	Medium = 3	
Handling frequency	1	1	1	1	1	1	1	Higher = 5	
SXT manufacturability Merit, lower is better	3	3	3	7	11	11	11		
Score	+	+	+	0	-	-	-		
Detector Calibration Effort									
# Instruments to cross-calibrate	20	20	18	9	6	4	4		
Detector Calibration Effort Merit, lower is better	20	20	18	9	6	4	4		
Score	-	-	-	0	+	+	+		

+	0	-
Lower risk	Average risk	Higher risk

Technical Risk Factors (cont'd)

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope			
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/B	XH-25/1/4B	XH-25/1/4B-M	Weighting	Factor
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
System Testing Issues									
Thermal Vacuum testing								Likely	1
Flight configuration possible?	likely	likely	likely	possibly	possibly	possibly	possibly	Possibly	2
EOB Deployment testing									
g-negation system	n/a	n/a	n/a	lower	medium	higher	higher	Lower	1
								Medium	2
Light Tightness testing complexity	medium	medium	medium	medium	medium	medium	medium	Higher	3
System Testing Merit, lower is better	3	3	3	5	6	6	6		
Score	+	+	+	0	-	-	-		
Testability									
XRCF Modifications necessary	no	no	no	possible	yes	yes	yes	Possible	1
								Yes	2
Testability Merit, lower is better	0	0	0	1	2	2	2		
Score	+	+	+	0	-	-	-		

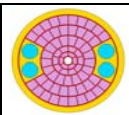
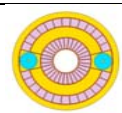
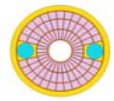
System Testing Issues

+	0	-
Lower risk	Average risk	Higher risk

Testability

+	0	-
No changes	Possible changes	Changes

Programmatic Factors

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope			Weighting	Factor
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4/B	XH-25/1/4B	XH-25/1/4B-M		
Naming Convention:	[bench type] - [FL] / [# of tel.] / [tel. dia.] [tel. type]								
Telescope Layout									
Program Risk Factors									
EOB Single Source Procurement	n/a	n/a	n/a	n/a	n/a	Yes	Yes	Yes	1
Program Risk Factors Merit, lower is better	1	1	1	1	1	2	2		
Score	0	0	0	0	0	-	-		
Schedule Drivers									
Mandrel Procurement (Estimated number of mandrels)	432	432	596	678	1204	524	782		
Program Cost/Schedule Drivers Merit, lower is better	1.00	1.00	1.38	1.57	2.79	1.21	1.81		
Score	+	+	0	0	-	+	-		
Technology Readiness									
XMS	1	1	1	2	3	3	3	current plan	1
RGS	1	1	1	1	1	1	1	small change	2
HXT	1	1	1	1	2	2	2	big change	3
SXT	1	1	1	1	2	2	2		
Technology Readiness Merit, lower is better	4	4	4	5	8	8	8		
Score	+	+	+	0	-	-	-		

Program Risk Factors

+	0	-
Lower risk	Average risk	Higher risk

Schedule Drivers

+	0	-
Relative to Baseline		
< 1.33	< 1.66	

Technology Readiness

+	0	-
current plan	small change(s)	big changes

Summary

Family	Reference Baseline (total)	Fixed Bench		Deployed Multiple Telescopes	Single Telescope		
Configuration ID	(F-10/1/1.6A)x4	F-10/4/1.6A	F-11/3/1.8A	X-15/2/2A	X-20/1/4B	XH-25/1/4B	XH-25/1/4B-M
Telescope Layout							
Technical Criteria Summary (+, 0, -)							
PERFORMANCE							
System Perf. EA Margin	+	0	-	-	+	0	+
S/N Figure of Merit	0	+	+	-	+	-	+
S/BG Figure of Merit	0	+	0	-	-	-	-
Time to complete TRIP Science	0	0	-	-	0	-	+
REDUNDANCY	+	+	+	0	-	-	-
COST / SCHEDULE PROXIES							
System Mass Margin	-	0	+	+	-	+	0
System Complexity	-	-	-	0	+	+	0
Instrument Complexities							
XMS	+	+	+	0	-	-	-
RGS	-	-	0	+	+	+	+
HXT	-	-	-	+	+	+	+
Technical Risk Factors							
Optical bench factors	+	+	+	0	0	-	-
SXT manufacturability	+	+	+	0	-	-	-
Detector calibration	-	-	-	0	+	+	+
System testing issues	+	+	+	0	-	-	-
Testability	+	+	+	0	-	-	-
Program Risk Factors							
EOB single source procurement	0	0	0	0	0	-	-
Schedule drivers	+	+	0	0	-	+	-
Technology readiness	+	+	+	0	-	-	-
Totals							
+	9	10	9	3	6	6	6
0	4	4	4	11	3	1	2
-	5	4	5	4	9	11	10